Atty. Dkt. 461-173
ND,NJ-P091-US

U.S. PATENT APPLICATION

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Invention: METHOD FOR SUPPRESSING FUEL EVAPORATION FROM FUEL STORAGE DEVICE, AND FUEL STORAGE DEVICE

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SPECIFICATION

METHOD FOR SUPPRESSING FUEL EVAPORATION FROM FUEL STORAGE DEVICE, AND FUEL STORAGE DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for suppressing fuel evaporation from a fuel storage device and to a fuel storage device.

2. Description of the Related Art

In an internal combustion engine utilizing a highly volatile fuel oil, such as gasoline or the like, a fuel vapor processing device is provided in order to prevent the discharge, into atmosphere, of fuel vapor generated in a fuel storage tank of a fuel storage device. The fuel vapor processing device adsorbs the fuel vapor into an adsorbent in a canister. During operation of the internal combustion engine, the adsorbed fuel vapor is purged (separated from the absorbent) using the negative pressure of an intake manifold, is fed to an intake system of the internal combustion engine, and is burnt together with the fuel normally supplied from an injector in a combustion chamber of the internal combustion engine.

In a direct injection type internal combustion engine burning fuel in stratified combustion, or in an internal combustion engine mounted on a hybrid vehicle using both an internal combustion engine and an electric motor to supply the driving force, throttle valve opening degree is set relatively close to full-throttle side so that the the negative pressure of the intake manifold tends to be low and that the purging capability for the fuel vapor is reduced.

As regulations concerning exhaust emissions are becoming more and more severe and, hence, precise control of fuel combustion becomes more and more necessary, the permissible amount of fuel vapor that can be processed by

combustion in an internal combustion engine is unavoidably limited.

Therefore, in Patent Reference 1 below, a method is proposed in which, in order to reduce generation of fuel vapor in a fuel tank, a condenser having a cooling means using a semiconductor device is used to condense and liquefy the fuel vapor. In Patent Reference 2, a method is proposed in which a fuel chamber formed of an elastic film is provided in a fuel tank having a pressure-proof structure so that fuel can be stored in the fuel chamber and the fuel tank outside of the fuel chamber is maintained at a predetermined pressure using a pressurizing pump. In this method, generation of fuel vapor is reduced by maintaining the vapor pressure in the fuel chamber at a constant level. Also in Patent Reference 3 below, a method is proposed in which a separation membrane is provided that moves vertically in accordance with the amount of stored fuel to separate the fuel portion from the gas portion, and the separation membrane is inclined so that the position of a higher part of the separation membrane is nearer to a port communicating with a canister. In this method, even if wrinkles are formed in the separation membrane, fuel vapor is confined to the space formed by the wrinkles so that the fuel vapor is temporarily prevented from being fed to the canister, thereby eliminating the need of a large scale canister.

[Patent Reference 1]

Japanese Patent Publication No. 11-93784.

[Patent Reference 2]

Japanese Patent Publication No. 08-324266.

[Patent Reference 3]

Japanese Patent Publication No. 09-203359.

However, in the method proposed in Patent Reference 1 or Patent Reference 2, it is necessary to operate the semiconductor device or the pressurizing pump in order to decrease generation of fuel vapor, and the

power consumption for these devices necessarily lowers the vehicle fuel consumption efficiency. If these devices are operated after the internal combustion engine is stopped, they become a large burden. It is undesirable that the semiconductor device or the pressurizing pump remains in operation in the absence of an operator after the internal combustion engine is stopped. Moreover, a pipeline system including a condenser and the pressurizing pump or a control system for the semiconductor device or the pressurizing pump unnecessarily complicate the construction, resulting in increase of cost. The complicated construction prevents easy mounting of the devices, and a recent demand for a smaller vehicle size and a larger free space in a passenger compartment cannot be sufficiently met. Also a pressure-proof structure of the tank is required in the method of Patent Reference 2 in which the pressurizing pump is used.

On the other hand, in the method proposed in Patent Reference 3, power consumption is not required and the construction is simple in comparison with Patent References 1 and 2. However, the method is directed to prevention of the feeding of a large amount of fuel vapor from a tank to a canister at one time, to thereby reduce the size of the canister. The amount of fuel vapor generation cannot be effectively suppressed by this method.

SUMMARY OF THE INVENTION

It is an object of the present invention to solve the above-described problem and to provide a method for suppressing evaporation of fuel in a fuel storage device and a fuel storage device capable of effectively suppressing generation of fuel vapor.

In accordance with a first aspect of the present invention, a method for suppressing evaporation of fuel in a fuel storage device having a tank for storing fuel is provided: wherein, when fuel temperature increases

into a high temperature range where saturated vapor pressure of the stored fuel varies in a relatively large magnitude according to the fuel temperature change, heat storage material is used to absorb heat from the stored fuel to thereby suppress the temperature rise of the stored fuel; and, when fuel temperature decreases into a low temperature range where the saturated vapor pressure of the stored fuel varies in a relatively small magnitude according to fuel temperature change, the heat absorbed by the heat storage material is radiated from the heat storage material to the stored fuel; and wherein, when heat is radiated from the heat storage material to the stored fuel, effect of suppression of decrease in the saturated vapor pressure is small; and when heat is absorbed from the stored fuel to the heat storage material, effect of suppression of increase in the saturated vapor pressure is larger than that of the suppression of the decrease in the saturated vapor pressure, thereby resulting in a suppression of fuel evaporation.

Heat is exchanged between the heat storage material and the stored fuel. The stored fuel exhibits large rate of change in the saturated vapor pressure with respect to temperature change in the high temperature range, and small rate of change in the saturated vapor pressure with respect to temperature change in the low temperature range. Therefore, the effect of the heat storage material for suppression of rise in saturated vapor pressure when the heat storage material is used for suppression of rise in stored fuel temperature is more effective than the effect of the heat storage material for suppression of reduction in saturated vapor pressure when the heat storage material is used for suppression of reduction in stored fuel temperature. Thus, overall effect of the heat storage material is suppression of fuel evaporation.

Although fuel evaporation is increased due to the

action of the heat storage material in the low temperature range, as saturated vapor pressure itself in the low temperature range is lower than that in the high temperature range, an excessive amount of evaporated fuel is not generated in the low temperature atmosphere.

In this manner, fuel evaporation can be effectively suppressed by the heat storage material.

In accordance with a second aspect of the present invention, a fuel storage device comprising a tank for storing fuel has heat storage means which contain heat storage material and exchange heat with fuel stored in the tank.

Heat is exchanged between the heat storage material and the stored fuel. The stored fuel exhibits a large rate of change in the saturated vapor pressure with respect to temperature change in the high temperature range, and a small rate of change in the saturated vapor pressure with respect to temperature change in the low temperature range. Therefore, the effect of the heat storage means for suppression of rise in saturated vapor pressure when the heat storage means are used for suppression of rise in stored fuel temperature is more effective than the effect of the heat storage means for suppression of reduction in saturated vapor pressure when the heat storage means are used for suppression of reduction in stored fuel temperature. Thus, overall effect of the heat storage means is the suppression of fuel evaporation.

Although fuel evaporation is increased due to action of the heat storage means in the low temperature range, as saturated vapor pressure in the low temperature range is lower than that in the high temperature range, an excessive amount of evaporated fuel is not generated in the low temperature atmosphere.

In this manner, fuel evaporation can be effectively suppressed by the heat storage material.

In a third aspect of the present invention according

to the above-mentioned second aspect a fuel storage device is provided, wherein the heat storage means are disposed on an inner surface of the tank or on surfaces of members immersed in the stored fuel.

With this construction, heat exchange between the heat storage means and the stored fuel is facilitated and evaporation of fuel can be effectively suppressed.

In a fourth aspect of the present invention according to the above-mentioned second aspect a fuel storage device is provided, wherein the said heat storage means comprise buoyancy generating means for generating buoyancy in the stored fuel.

With this construction, the heat storage means are always positioned near the liquid surface of the stored fuel due to buoyancy. As the evaporation of fuel takes place at the liquid surface of the stored fuel, the heat storage means exchange heat effectively with the fuel near the liquid surface of the fuel and, thus, can further suppress the evaporation of fuel.

As the heat storage means are present near the liquid surface, the contact area of the stored fuel with air above the liquid surface is decreased, which also contributes to suppression of fuel evaporation.

In a fifth aspect of the present invention according to the above-mentioned fourth aspect a fuel storage device is provided, wherein the heat storage means have containers each of which has heat storage material sealed therein and in each of which an empty portion having no heat storage material is provided and serves as the buoyancy generating means.

This construction is simple in that, other than the container and heat storage material, no additional member, such as a float or the like, must be provided.

In a sixth aspect of the present invention according to the above-mentioned fifth aspect a fuel storage device is provided, wherein the containers have diameters greater than a diameter of inlet port of a fuel pump

sucking fuel from the tank.

With this construction, the heat storage means can be prevented from being inadvertently sucked into the fuel pump when the amount of stored fuel in the tank is decreased.

In a seventh aspect of the present invention according to any one of the above-mentioned aspects 2 to 6 a fuel storage device is provided, wherein the heat storage means have containers each of which has the heat storage material sealed therein and the heat storage material is formed of a substance which has a melting point at an ordinary temperature and stores heat as latent heat.

By utilizing latent heat, large amount of heat can be absorbed or radiated even if small heat storage means are used.

In accordance with a eighth aspect of the present invention according to the above-mentioned seventh aspect a fuel storage device is provided, wherein the heat storage material includes any one selected from calcium chloride 6 (hexa)-salt, octadecane, and cyclohexanol.

These substances have melting points in the range of 20 ~ 30 °C, and have relatively large heat of fusion, and hence are suitable for suppression of fuel evaporation.

The present invention may be more fully understood from the description of the preferred embodiments of the invention set forth below, together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1 is a view showing a fuel storage device according to a first embodiment of the present invention;

Fig. 2 is a sectional view showing a heat storage piece constituting said heat storage device;

Fig. 3 is a graph useful for explaining the operation of said heat storage device;

Fig. 4 is a view showing a fuel storage device

according to a second embodiment of the present invention;

Fig. 5 is a view showing a fuel storage device according to a third embodiment of the present invention;

Fig. 6 is a sectional view showing a heat storage piece constituting said heat storage device;

Fig. 7 is a view showing a fuel storage device according to a fourth embodiment of the present invention; and

Fig. 8 is a sectional view taken at A of Fig. 7.

DESCRIPTION OF PREFERRED EMBODIMENTS

(First embodiment)

Fig. 1 is a view showing a fuel storage device according to a first embodiment to which a method for suppressing fuel evaporation in a fuel storage device of the present invention is applied. The fuel storage device comprises a synthetic resin tank 11 with a capacity of several liters (L), and a fuel neck 21 penetrating the tank wall is connected to the top end of the side wall portion of the tank, with an oil supply port 22 at one end thereof. A fuel pump 31 is provided in the tank 11, and feeds fuel sucked from an inlet port, not shown, to a fuel pipeline 41 penetrating the tank wall and communicating with an injector not shown. To the ceiling of the tank 11, a fuel vapor pipeline 42 penetrating the tank wall is connected so as to feed the fuel vapor generated in the tank 11 to a canister not shown. The inside of the tank 11 is divided in a horizontal direction by partition plates 12, 13. These plates are members immersed in stored fuel, and holes are punched in them in the direction of thickness of the plates. Some movement of stored fuel F is allowed by these holes, although rapid movement of stored fuel F at the time of acceleration or deceleration or tilting of a vehicle is avoided.

A multiplicity of heat storage pieces 5 as a heat storage means are attached to an inner surface 11a of the

tank 11 and to plate surfaces 12a, 13a of the partition plates 12, 13. A heat storage piece 5 is a small container 51, as shown in Fig. 2, having heat storage material 52 sealed therein. The small container 51 is made of heat-resistant, fuel-resistant, synthetic resin or the like shaped into a hollow rectangular parallelopiped. Sealing of the heat storage material 52 is carried out by placing solid heat storage material 52 into split-halves of the small container 51 and then by fusing and bonding together the opening edges of the split-halves. As the heat storage material 52, calcium chloride hexa (6)-hydrate ($CaCl_2 \cdot 6H_2O$), for example, may be used. Calcium chloride 6-hydrate has melting point of 27 °C and exhibits phase transition between a liquid phase and a solid phase at an ordinary temperature. As the heat storage material 52, a substance having melting point at ordinary temperature in the range of 20 ~ 30 °C is preferably used and, in addition to an inorganic hydrated salt, such as above-mentioned calcium chloride 6-hydrate, organic compounds may be used. Examples of organic compounds suitable to be used as the preferable heat storage material 52 includes, for example, octadecane ($C_{18}H_{38}$) with melting point at 28 °C and cyclohexanol ($C_6H_{12}O$) with melting point at 24 °C. Mixtures of these compounds, or containing these compounds as main components, may also be used.

The sealed amount of the heat storage material 52 is chosen to be less than the capacity of the small container 51. Therefore, an empty portion 53 having no heat storage material 52 is provided in the small container 51. The small container 51 is thereby prevented from being damaged by volume expansion of the heat storage material 52 at the time of phase transition from a solid to a liquid phase.

When temperature of the stored fuel F rises, due to operation of the fuel pump 31 at the time of vehicle operation or to temperature rise of the atmosphere, or

the like, above the melting point of the heat storage material 52 of the heat storage piece 5, the heat storage material 52 begins to melt. As the heat storage material 52 takes away heat corresponding to heat of fusion from the fuel surrounding the heat storage material 52, the fuel is cooled thereby. By suitably setting the amount of heat storage material 52 placed in the tank 11, the fuel can be maintained at temperature not higher than that of the heat storage material 52 even when heat is absorbed to the extent of complete melting of the heat storage material 52. If, for example, calcium chloride 6-hydrate is used as the heat storage material 52, when the fuel temperature reaches its melting point of 27 °C, the heat storage material 52 melts, takes away heat from the stored fuel F and cools the stored fuel F. Thus, if in this fuel storage device of the present embodiment, fuel temperature is kept at 27 °C by melting of the heat storage material 52 and if in conventional fuel storage device having no heat storage piece 5, it is assumed that fuel temperature rises to 37 °C, a difference in saturated vapor pressure occurs between the fuel storage device of the present embodiment and the conventional fuel storage device, as can be seen from Fig. 3. Therefore, in the fuel storage device of the present embodiment, an increase of the saturated vapor pressure is suppressed. Thus, with the fuel storage device of the present invention, evaporation of fuel corresponding to the area of the region A in Fig. 3 can be suppressed.

Then, when the fuel temperature falls, due to stopping the operation of the fuel pump 31 or due to lowering of atmosphere temperature, and reaches the melting point of the heat storage material 52, solidification of the heat storage material 52 takes place, whereby heat is radiated to the surrounding stored fuel F. As a result, the stored fuel F is warmed up. If it is assumed that the amount of radiated heat corresponds to a change in fuel temperature of 10 °C, a

difference in saturated vapor pressure arises between the fuel storage device of the present embodiment and a conventional fuel storage device. That is, in the fuel storage device of the present embodiment, a decrease of saturated vapor pressure is suppressed. Thus, with the fuel storage device of this embodiment, evaporation of fuel corresponding to area of the region B in Fig. 3 is promoted.

Thus, both suppression and promotion of fuel evaporation is induced by the heat storage action of the heat storage material 52 in the heat storage piece 5. As saturated vapor pressure varies as an exponential function with respect to temperature, rate of change in saturated vapor pressure with respect to change in temperature increases in accordance with a temperature increase. Therefore, even with same temperature change of 10 °C, the effect of suppression of the increase of saturated vapor pressure is larger than the effect of suppression of the decrease in saturated vapor pressure. Thus, the effect of suppression of fuel evaporation is larger and, comparing the gain with the loss, overall effect of the heat storage piece 5 is suppression of fuel evaporation.

In the first embodiment, the heat storage pieces 5 are not disposed on all of the inner surface 11a of the tank 11 and plate surfaces 12a, 13a of the partition plates 12, 13 immersed in the stored fuel F, but a part of these surfaces is not provided with the heat storage pieces 5 in accordance with the required amount of heat storage, so that the heat storage pieces 5 are not installed, for example, on the bottom surface of the tank inner surface 11a, as shown in Fig. 4.

Also, depending upon the coefficient of volume expansion of the heat storage material or of the small container, the empty portion where no heat storage material is placed is not required to avoid damage to the small container, and the volume of the heat storage piece

can be reduced (which means higher volume efficiency).

(Second embodiment)

Fig. 5 is a view showing a fuel storage device according to a second embodiment to which the method for suppressing fuel evaporation of the present invention is applied. Substantially the same parts as in the first embodiment are denoted by the same reference numerals, and the following description of the second embodiment will be focused on the difference from the first embodiment.

A multiplicity of heat storage pieces 5A float on the stored fuel F in the tank 11. The heat storage piece 5A has a shape different from that of the heat storage piece 5 in the first embodiment.

The heat storage piece 5A is sealingly filled with heat storage material 52A in a small container 51A, and differs from the heat storage piece in the first embodiment in that the small container 51A has a spherical shape. The heat storage pieces 5A are not fixed to the tank inner surface 11a or to the partition plates 12a, 13a, but float on the stored fuel F.

In the small container 51A in which the heat storage material 52A is sealingly filled, there is provided an empty portion 53A where no heat storage material 52A is filled, as in the first embodiment. This empty portion 53A, as a buoyancy generating means, generates buoyancy in accordance with its volume. The size of the empty portion 53A with no heat storage material formed is set so as to generate buoyancy sufficient to make the heat storage piece 5A float on the stored fuel F. It is to be understood that the empty portion 53A with no heat storage material formed has the effect of preventing the small container 51A from being damaged at the time of liquefaction of the heat storage material 52A.

The effect of suppressing fuel evaporation can be obtained also with the heat storage pieces 5A of the present embodiment. In addition, fuel evaporation in an

atmosphere at an ordinary temperature is not due to the boiling of fuel and occurs at the liquid surface of the stored fuel F. Therefore, as the heat storage pieces 5A are positioned at the liquid surface of the stored fuel F owing to the buoyancy due to the empty portion 53A having no heat storage material, evaporation of fuel can be effectively suppressed. The contact area between the stored fuel F and the air above the liquid surface is decreased by presence of the heat storage pieces 5A near the liquid surface, which can further suppress evaporation of the stored fuel F.

Diameter of the small container 51A is chosen to be larger than diameter of the inlet port of the fuel pump 31 in order to prevent the heat storage pieces 5A from being sucked into the fuel pump 31 when the amount of remaining fuel is decreased and the level of the stored fuel F, i.e. the position of the heat storage pieces 5A, comes close to the inlet port of the fuel pump 31.

The heat storage pieces 5A may be linked with a flexible wire in a row or in units of several pieces in rows, in the tank 11. In this way, they can be conveniently grouped as attached component of the fuel storage device and can be easy to handle.

By providing, in the small container, an empty portion which has no heat storage material, the heat storage piece can float on the stored fuel without comprising an additional float or the like other than the small container and the heat storage material and can be simplified in construction. It is to be understood that floats may be additionally provided as required by a specification.

In the embodiments described above, the small container constituting the heat storage piece is of rectangular or spherical shape. The present invention is not limited to these shapes, and various other shapes, such as a square or the shape of a rugby ball, may be used.

(Third embodiment)

Fig. 7 and Fig. 8 are views showing a fuel storage device according to a third embodiment to which the method for suppressing fuel evaporation of the present invention is applied. Substantially same parts as in the first embodiment are denoted with the same reference numerals, and the following description will be focused on the difference of the third embodiment from the first embodiment.

The basic construction of the fuel storage device of the present embodiment is the same as a conventional fuel storage device. No heat storage piece as in the first and the second embodiment is not provided. Fig. 8 is a sectional view showing a tank wall of the tank 11A of this fuel storage device, and a multiplicity of micro-capsules 51B, as small containers, are included in a synthetic resin substrate 111 forming the tank wall. Each micro-capsule 51B is as small as a few μm to a few hundreds μm, and the heat storage material 52B which constitutes the heat storage means 5B together with the micro-capsule 51B is sealingly filled therein. Micro-capsules 51B are prepared, in advance, with the heat storage materials 52B sealed therein, and these micro-capsules 51B are mixed into the synthetic resin to be used to form the tank wall. The synthetic resin containing these micro-capsules is molded into a shape of a tank to obtain the tank 11A.

As the heat storage device according to this embodiment is formed by mixing the heat storage means into the inside of the tank wall, the shape of the tank can be made substantially the same as a conventional fuel storage device. Therefore, the same assembling procedure or same type of parts as a conventional fuel storage device can be used, and therefore, the application thereof to actual vehicles becomes particularly easy.

While the invention has been described by reference

to specific embodiments chosen for the purposes of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.